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Agricultural Memorandum No 974

THE VARIABILITY OF RELATIVE HUMIDITY FOR GRAIN DRYING.

Summary:

The relative humidity of the air, measured using dry bulb and wet bulb thermometers in a louvered screen 1.2 m above grass covered ground, varies during the day, from day to day, from month to month and from year to year. This variability is analysed by comparing the day to day changes with the average values with particular reference to the Autumn months. Also the changes related to the different types of prevailing weather. Finally the geographical variations of relative humidity are considered although the large spaces between meteorological stations justifies only schematic maps being produced.

Introduction:

The most common method of preserving grain on farms today is by drying the grain to a suitably low moisture content. All methods rely on the same basic principle of passing suitably dry air past the grain which gives up some moisture to the air which in turn carries the moisture away. The principles of grain drying, cooling and ventilating for storage are well documented, eg the ADAS Illustrated Guide to the Principles of Managing Bulk Grain Driers, March 1983, and the Electricity Council's Farm Electric Handbook. These publications and others like them briefly refer to average or typical weather conditions, ie a 10-year or longer average for a particular month. These averages are useful for assessing the average grain drying potential of the air at different times of the year. Additional information on the variation from year to year may be useful if for example equipment is required to cope with a one year in ten cool wet Autumn.

The day to day variations of the weather also affect the grain drying operations and an assessment of the effects of the prevailing weather type can help weekly planning and operating of the equipment.

The effects of temperature and relative humidity on the grain drying potential of the air are inter-related but the variations of relative humidity are of paramount importance, see Table 1.

Table 1

Drying capacities of air (kg per Day at 1 m³ per sec)

Temperature °C	Relative Humidity	Drying Capacity
10	80	50
15	80	60
20	80	70
10	70	90
15	70	105
20	70	125
10	60	140
15	60	155
20	60	180

Temperature is important but its variability is well understood, relatively easy to measure and usually included in weather bulletins. In any case supplementary heating can be used to increase the temperature and this has the added advantage of lowering the relative humidity of the air. The benefit of supplementary heating is best described by an example:-

Air at 15°C and 80% RH when warmed by 5°C increases its drying capacity from about 60 units (see Table 1) to 200 units: this is comparable to air at 15°C and 50% RH.

The importance of humidity together with the sparsity of information on its variability and its relationship to the other weather variables such as rain, showers, wind and temperature justify a simple descriptive paper. In this paper the humidity will always be expressed as a percentage, ie percentage of the maximum. The relative humidity is not an amount in itself; the amount of water vapour present can only be ascertained from the relative humidity if the temperature is specified.

Averages of Relative Humidity:

The variation of relative humidity is dominated by the diurnal variation (Variation during the day) and in Autumn it is at a maximum value in percentage terms at the coldest time of day, ie about dawn, and lowest at the warmest time of day, ie mid-afternoon. Therefore a comparison of yearly, monthly or daily values should be for the same time of the day.

The often quoted monthly averages of RH (10 years or longer) are compared with the actual monthly RH in individual years, 1974 to 1983 for August, see Table 2. The year to year variation is between - 16% (+8%) of 10 year average value. The year to year variation at other wetter or drier places is greater than this.

The importance of the yearly variation is that the grain drying requirement should perhaps be specified in terms of the one year in ten, say, rather than the average (5 years in 10). The requirement for supplementary heating would be more obvious if large throughputs are necessary in the cooler, wetter, Autumns as experienced one year in ten.

Table 2

Monthly RH for Individual Years at 0600 and 1500 hours at RAF Shawbury, Shropshire

Year	August 0600 hours	August 1500 hours
1973	92	65
1974	92	63
1975	93	58
1976	90	49
1977	93	69
1978	93	73
1979	86	72
1980	92	71
1981	93	64
1982	<u>91</u>	<u>71</u>
10-year Average	92	65

If the relative humidity on an average day in August is compared with that of an average day in January, see Fig 1 it is plain to see that the August values are much lower, particularly for the period from mid-morning until late evening. The main reason for this is that the days are much shorter in January and the usual track of depressions in Winter is across the Atlantic Ocean passing over or just

to the north of the British Isles. These depressions bring cloud and lengthy periods of rain. Even when it is not raining and it is not cloudy the sun's drying capacity is weak and short-lived in Winter. For example the average daily duration of bright sunshine in central England is about 1 hour in January and about 6 hours in July.

Although there is a large difference in the average RH between July and January the differences between the average values of relative humidity in July, August and September are relatively small as illustrated in Fig 1.

Day to Day Variations in Relative Humidity:

The variation of relative humidity on an average day in August, see Fig 1 is obtained by averaging the individual daily values. For example the variation of RH on an average summer day is compared with the variation on a rainy day and a very dry day in Summer in Fig 2.

The possible day to day changes in RH as depicted in Fig 2 are the largest variations which occur and their significance is highlighted by the fact that the RH on a rainy day in Summer (Fig 2) is higher than that for an average day in January (Fig 1).

The large day to day variation of RH are directly related to changes in the prevailing weather. The rainy days and the dry days only broadly account for the different RHs. Cloud, wind and showers have an important contribution to make directly and also indirectly through their effect on the temperature.

Continuous rain, whether this is light or heavy, maintains the air at between 95 and 100% RH. Intermittent slight rain, on the other hand, may only maintain the RH at between 80 and 90%, nearer 90 with light or calm winds and nearer 80 with moderate or fresh winds.

Occasional but short lived showers on a mostly cloudy day have a similar effect on RH to that produced by intermittent slight rain. However on a day with only a few showers but good sunny spells the RH fluctuates rapidly from 90% in the shower to as low as 60% an hour or two after the shower ends. This decrease in RH is in direct response to an increase in temperature. If there is a strong wind then this will greatly reduce the temperature rise but the drying effect of the strong wind will often make up the difference. Strong winds and/or cloud during the night reduced the fall in the surface air temperature and this helps to keep the RH low, see Fig 2.

Fig 3 illustrates the difference in RH on three consecutive days in August 1983. The 28th was a dry day with some sunshine, the 29th a similar but rather more cloudy day and the 30th a warmer day in the morning but cooler after an isolated shower occurred in the late morning.

Most of the relationships between weather events and the RH can be summarised by plotting the RH at 1500 hours, ie the dryest time of the day in Summer, on a typical weather map as depicted in Fig 4. The lower RH associated with the high pressure areas and the higher RH associated with the depression and its rain-bearing troughs (fronts) are clearly illustrated. Using this simple guide it is possible to relate the main features of the present or forecast weather pattern to derive a forecast RH for mid-afternoon. The RH at this time of day is the most sensitive parameter for showing the geographical variation of the drying capacity of the air on a particular day.

In areas of high pressure clear skies at night with light or calm winds allows maximum radiative cooling of the ground and the surface air. This often produces dense fog by about dawn which usually clears during the morning. The presence of

fog slows down the normal temperature increase and the RH stays near 100% until the fog clears. Fig 5 shows the RH on a foggy day in July. The wind was light or calm and the fog lifted to low cloud during the later morning and then dispersed completely soon after mid-day. As the Autumn progresses the longer nights and the shorter days accentuate the effects of mist and fog.

Geographical Variation of RH over England and Wales:

Assuming the air is at 100% RH at 0600 hours and no additional moisture is available to the air then the RH reduces dramatically as the air is warmed up. In practice some of the sun's energy is used to warm up the land and some is used to evaporate or transpire moisture from the ground and vegetation. However in general the effects on RH of the warming of the air outweigh those due to the increase of moisture through evaporation and transpiration. Thus the RH of the air is reduced.

Less cloud means more sunshine which means higher temperature and lower RH. In the UK the forced ascent of the air over hills results in these areas having relatively more cloud, lower temperatures and higher RH than many low lying areas, particularly on the windward side of hills, see Fig 6, therefore there are humidity shadows just as there are rain shadows.

In summer the coastal areas are usually cooler and more humid than inland areas during the day because of the sea breezes and the fact that sea temperatures at this time are cooler than land temperatures. Eg at mid-afternoon in August, see Fig 6, the coastal stations in South West England have similar relative humidities to those on the West Coast of Wales, the Lancashire Coast, and the Coast of North East England. The relative humidities on the South and South East Coasts are a little lower probably because of less exposure to prevailing winds from the West and North and the relative proximity to the large Continental landmass over which the air often travels when the wind is from the South and East.

There is little or no geographical variation of RH during the period from late evening until mid morning because the air is relatively cool and moist everywhere. Figs 7 and 8 show the variation of RH at 2100 and 0900 respectively of the relative humidity on an average day in August. All places other than those in urban cities show average values of RH of between 80 and 90%.

Conclusions:

An effective way of studying the daily and monthly variations of RH is to compare the values for the same time of day. The daily and monthly variations for 1500 hours offers single values comparisons, which with the air temperature, are useful indicators of the variations of the drying capacity of the air. The day to day variations of RH caused by the change in the weather are the largest variations that occur. These variations can be related to the actual and forecast weather conditions to help daily or weekly planning of grain drying operations.

The geographical variations of RH can be assessed by comparing the long term monthly averages for 1500 hours. The lowest relative humidities are in the London area but there is very little difference between inland areas from Greater Manchester southwards to Wiltshire, eastwards to East Anglia and northwards to the Vale of York. The RH is highest near Western and North East Coasts.

The grain drying capacity requirement may be best assessed by considering a typically wet Autumn as indicated by a once-in-10 year value of RH. A return period analysis of ambient air RH and temperature combined specifically for grain drying will be the subject of further study.

Any comments or suggestions on the contents of this paper should be addressed to the author.

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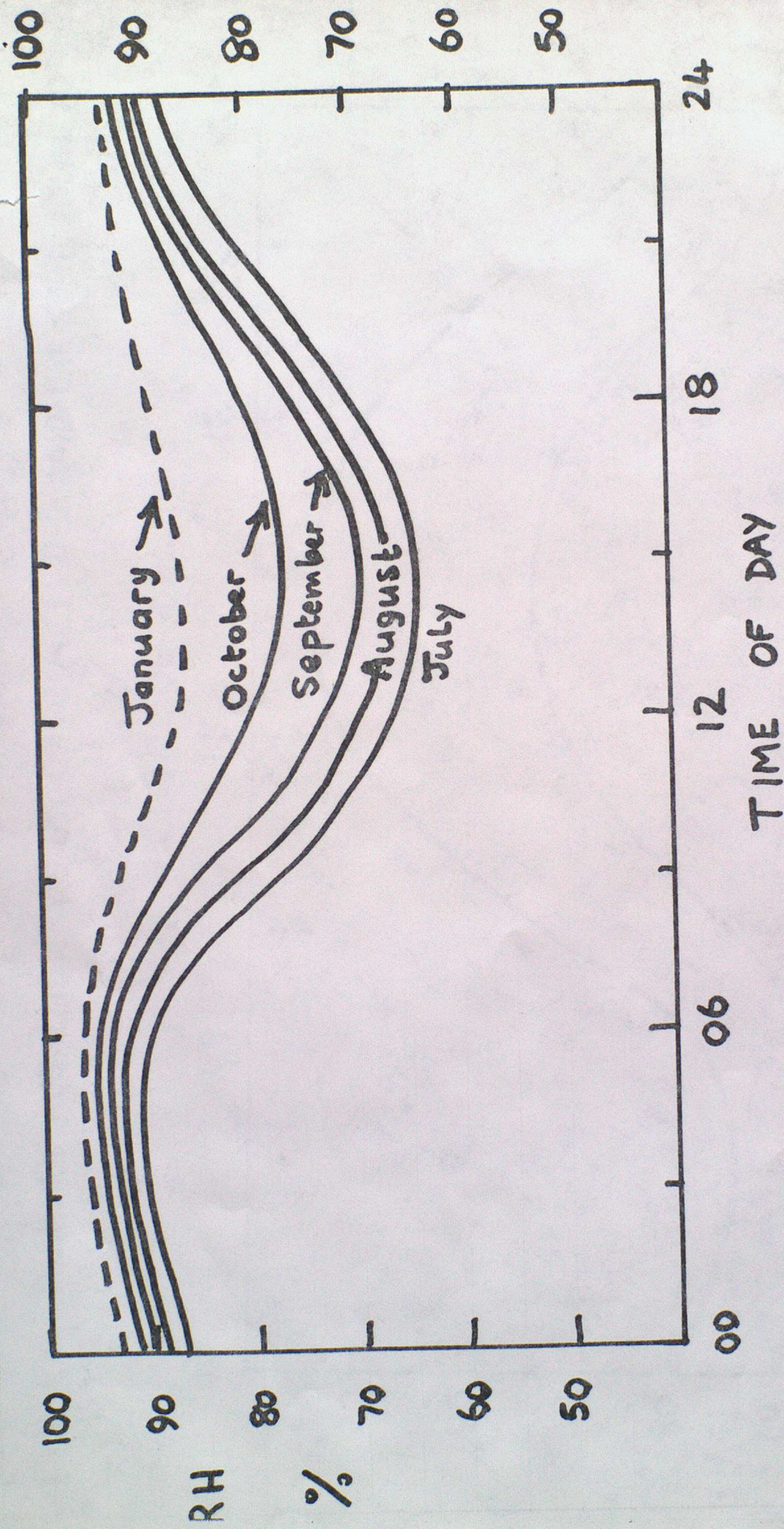


FIG 1 Average diurnal variation of RH in different months at RAF Shawbury, Shropshire

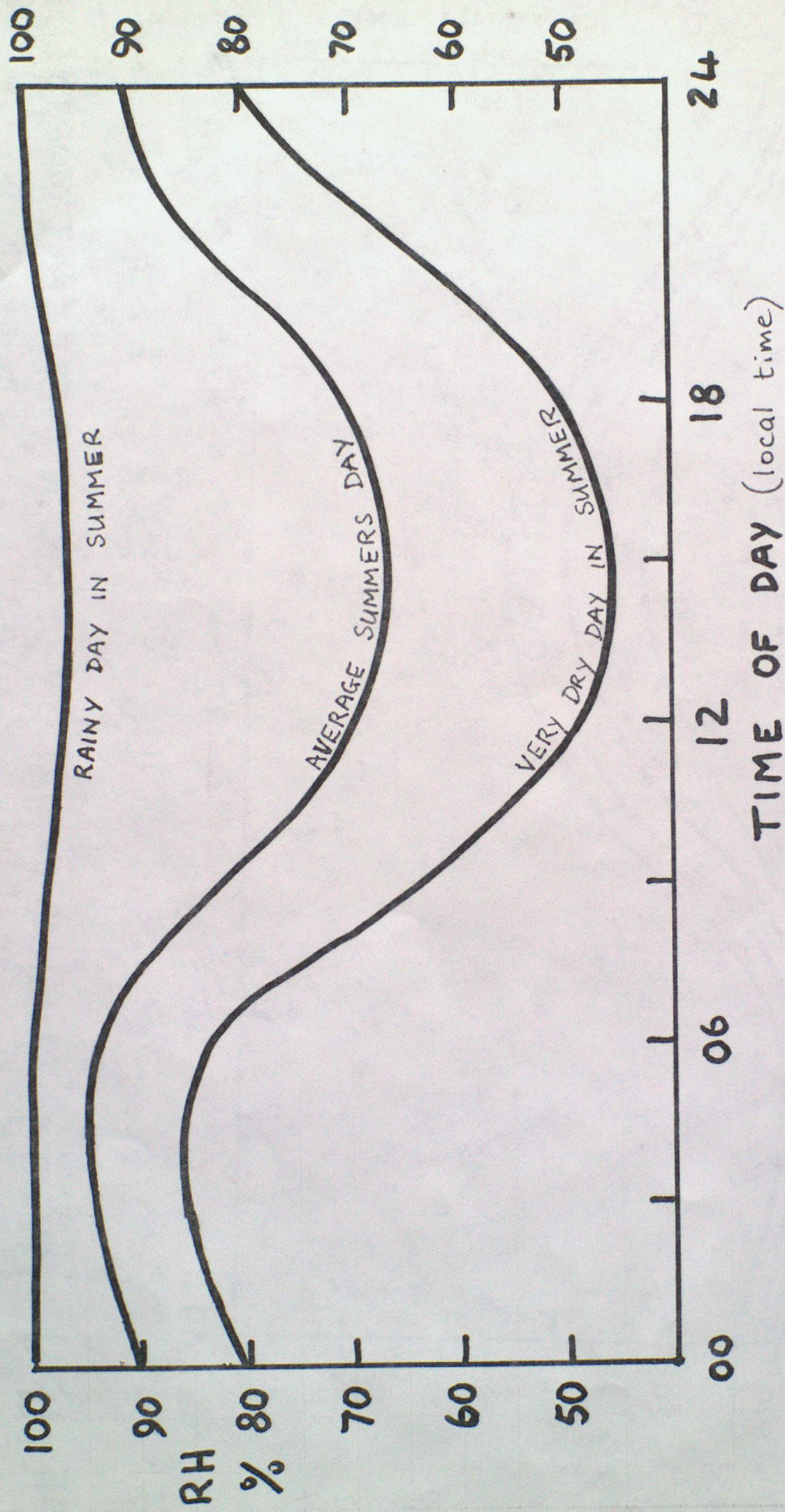


FIG. 2 DIURNAL VARIATION OF RH ON A WET, DRY AND AVERAGE SUMMERS DAY

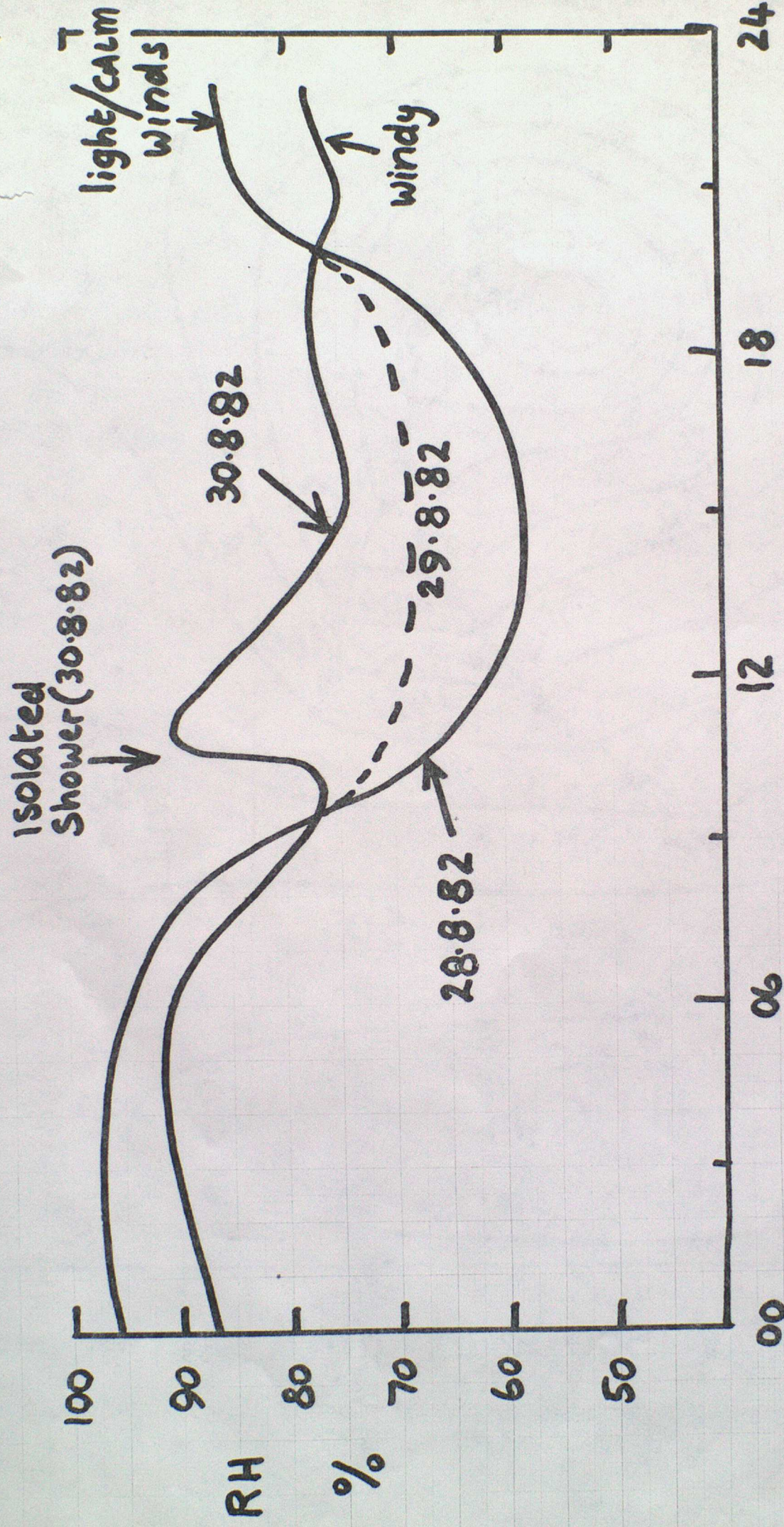


FIG 3 Actual variation of RH on three Days in August 1982 at RAF Shawbury, Shropshire

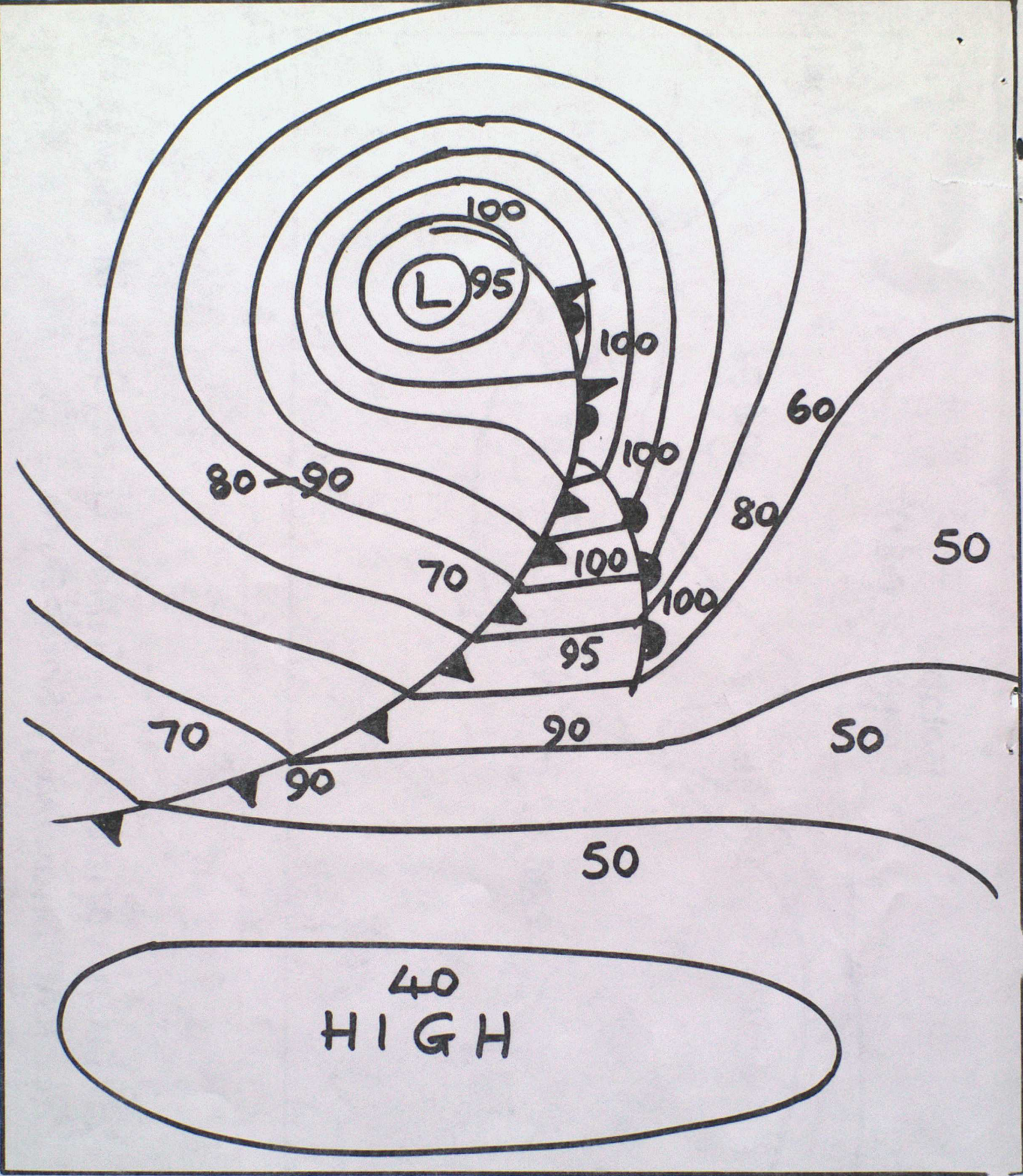


FIG 4. RH at 1500 hours on a weather map.

Note: This diagram is only schematic because some fronts are weaker than others and the presence of cloud and fog in areas of high pressure may increase RH.

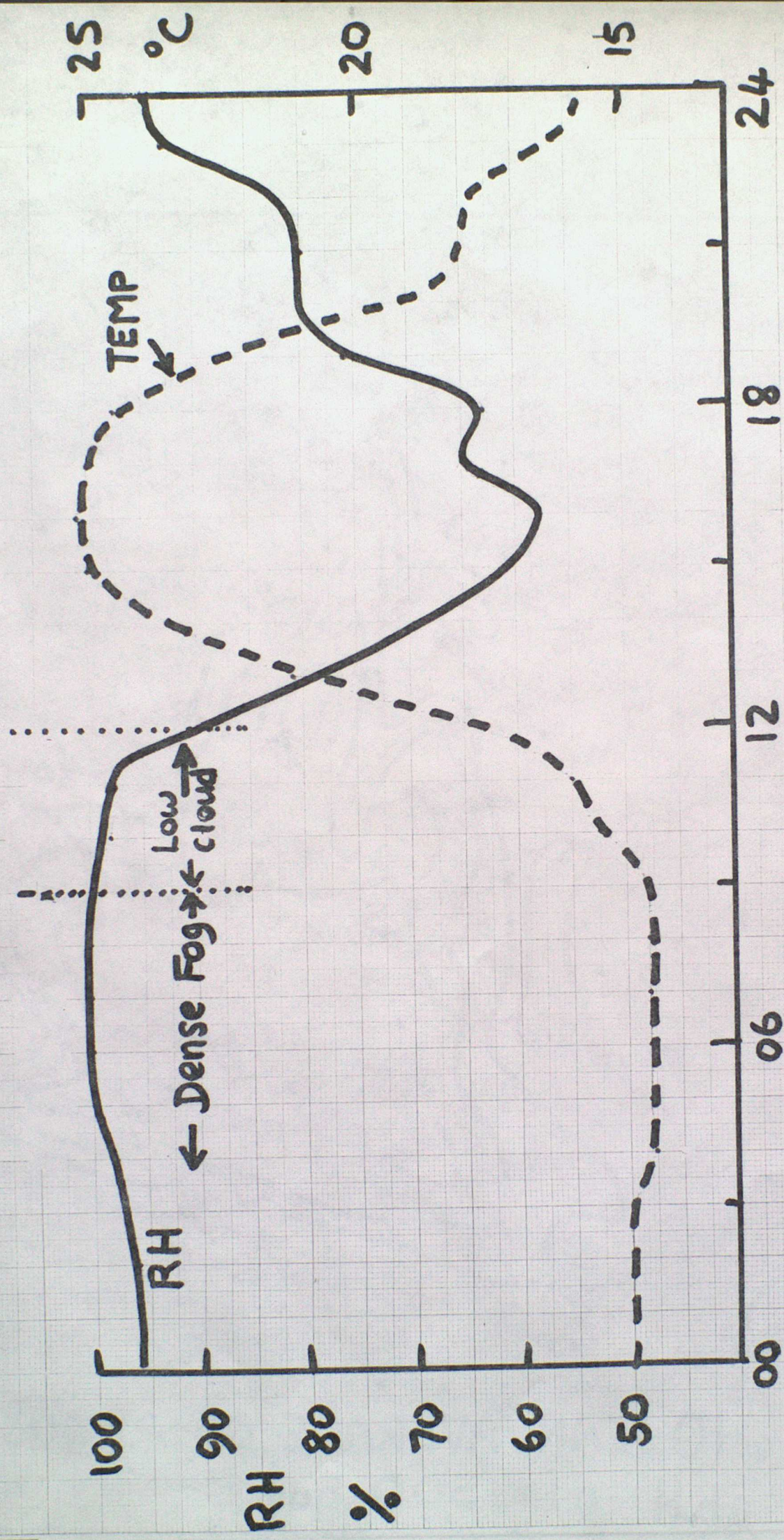


FIG 5 VARIATION OF RH and TEMPERATURE on 26.7.83
at RAF SHAWBURY, SHROPSHIRE

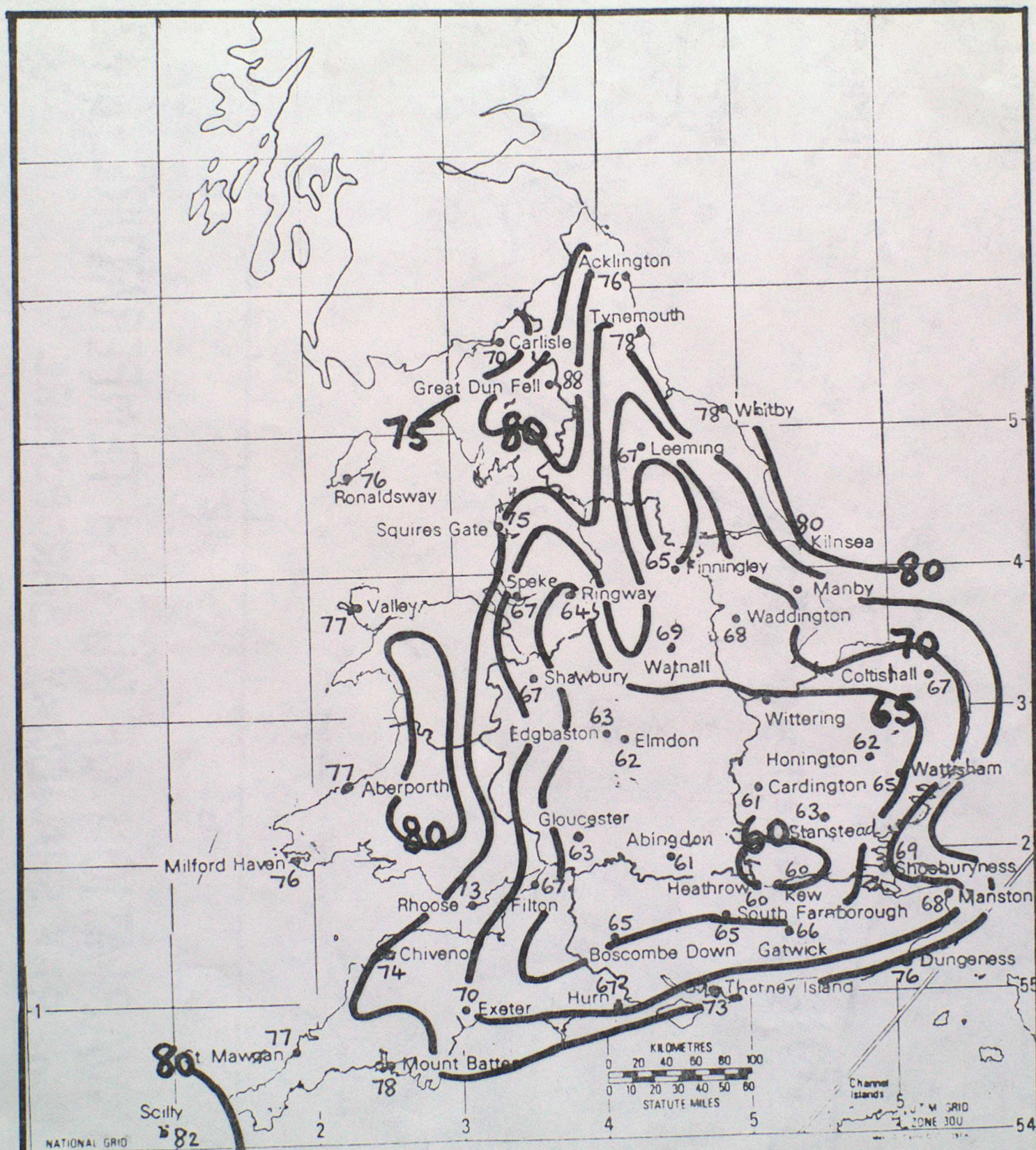


**FIG 6 10 YEAR AVERAGE OF AUGUST
RH at 1500 hours.**

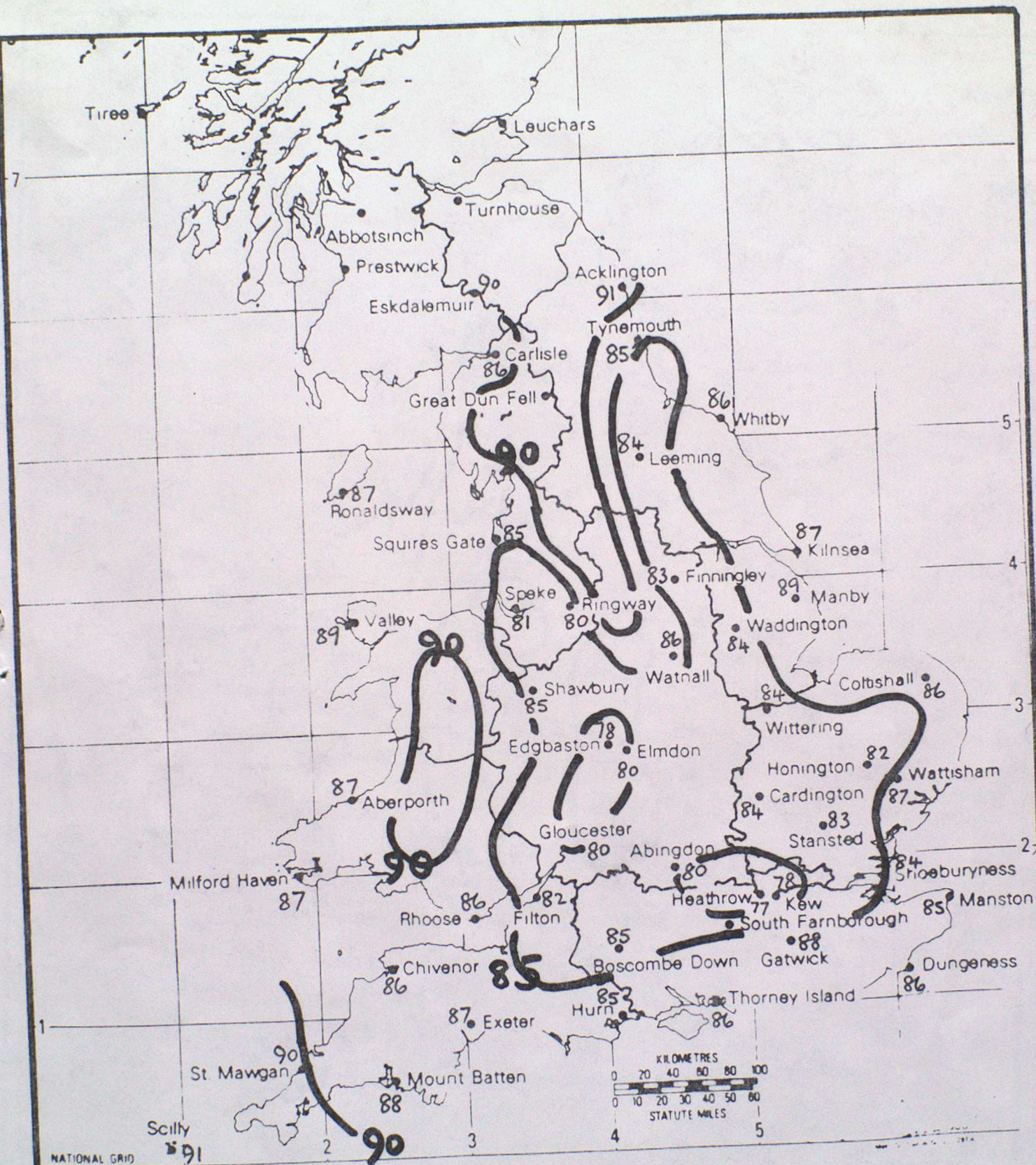


**FIG 7 10 YEAR AVERAGE - AUGUST
RH at 21 00 hours**

